Algorithms and Techniques for Environmental Sensing and Spacecraft Monitoring

Completed Technology Project (2016 - 2018)

Project Introduction

To achieve NASA's fundamental goals of continuing to explore and expand human and robotic presence to Mars and beyond (NASA Strategic Plan 2014, Objective 1), spacecraft must be able to identify hazards in their external environment and to monitor and respond to maintain their own system health, safety, and performance. The space environment both within our own magnetosphere and at interplanetary distances within our solar system has known hostile regions (such as the Van Allen Belts and the Jovian radiation environment) as well as unknown environments and the risk of significant disturbances from our Sun. For deep space exploration far from Earth, mission durations are longer and require more robust spacecraft systems that are risk-aware, have greater reliability, and can gracefully adapt to compensate for or respond to spacecraft aging and performance degradation. As spacecraft venture beyond distances where real-time command and control through communications systems is feasible, spacecraft must be able to inform on-board decision-making with little or no ground interaction. That capacity will require spacecraft not only to understand their external environments, but also to have software that can internally monitor the system and make decisions based on status. The primary deliverable will be a suite of algorithms used characterize the external environment and to detect atypical behavior in spacecraft telemetry, collecting the raw results across the spacecraft system and reporting the weighted results to on-board decision-making routines. By evaluating previous mission data compared to known space environment conditions (space weather events), I will determine the telemetry response to the external space environment. The telemetry response findings will be a deliverable of this proposal as well. Using the known telemetry responses, I will develop algorithms that will be able to characterize the external environment by matching on-board responses to the telemetry response findings corresponding to different space weather events. In addition, I will deliver technology that will detect and diagnose atypical performance and hiccups in their system or individual components on-board. In contrast to current spacecraft as a sensor methods (e.g. neural networks), the proposed algorithms do not make assumptions about the underlying distributions and does not impose any component- or satellite-specific parameters or thresholds. This approach is consistent with a general approach known as change-point detection and allows the algorithms to be used for the entire satellite system without operator input. By combining findings from the telemetry feeds using sensor fusion data association techniques (e.g. K-means), the spacecraft will be made more aware of it's own internal and external state, yielding a state estimation current health and performance state of the spacecraft system and the current state of the environment at any one time, allowing for autonomous and intelligent on-board decision-making. The findings through data analysis of previous mission data allow for more risk-aware algorithms for future missions. For example, NASA's Juno mission does not carry any space environment detectors. However, if information can be gathered from the Juno telemetry, valuable knowledge about the Jovian

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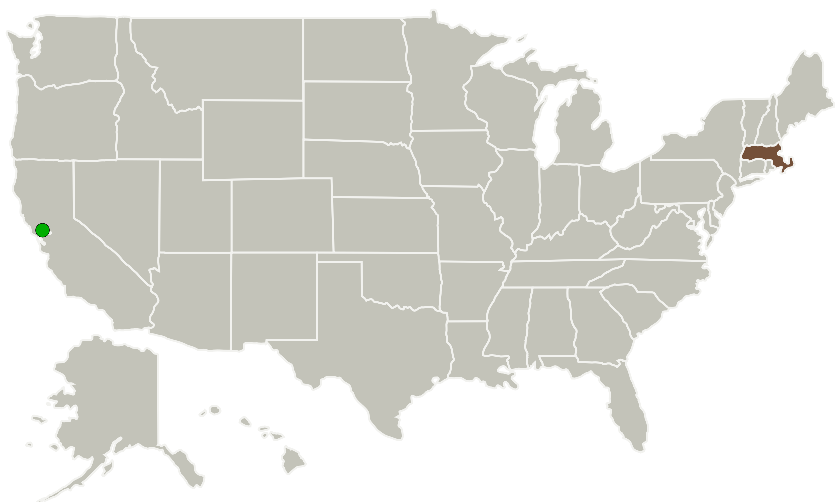
environment can be used for the Europa mission and other future Jovian missions. The proposed algorithms allow for longer mission durations by providing greater reliability to external environment hazards and adaptability to evolving missions. The proposed algorithms directly support Objective 1 in NASA's Strategic Plan to expand our human and robotic presence to Mars and beyond. The exploration leads to spacecraft encountering unknown and hazardous environments that the spacecraft will need to react to. Therefore, in addition, the proposed algorithms enable greater sustainability and risk reduction when integrated with FDIR systems.

Anticipated Benefits

Allows for longer mission durations by providing greater reliability to external environment hazards and adaptability to evolving missions, in addition to enabling greater sustainability and risk reduction.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Massachusetts Institute of Technology(MIT)	Lead Organization	Academia	Cambridge, Massachusetts
Ames Research Center(ARC)	Supporting Organization	NASA Center	Moffett Field, California

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Massachusetts Institute of Technology (MIT)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Kerri Cahoy

Co-Investigator:

Ashley Carlton

Space Technology Research Grants

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Primary U.S. Work Locations

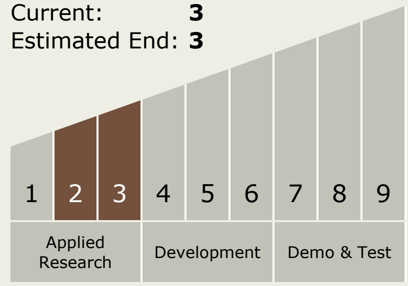
Massachusetts

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX10 Autonomous Systems
  └ TX10.1 Situational and Self Awareness
    └ TX10.1.2 State Estimation and Monitoring

Target Destinations

The Sun, Outside the Solar System